UFS-S2S Prototype 5 Benchmark Evaluation Summary

NATIONAL WEATHER SERVICE

Technical and Science Contributors

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Prototype Overview

	Initial Conditions					
	FV3 GFS	MOM6	CICE	WW3	Ice Model	Mediator
UFS_p1	CFSR	CFSR	CFSR	n/a	CICE5	NEMS
UFS_p2	CFSR	**CPC 3Dvar**	CFSR	n/a	CICE5	NEMS
UFS_p3.1	CFSR	CPC 3Dvar	**CPC ice analysis**	n/a	CICE5	NEMS
UFS_p4	CFSR	CPC 3Dvar	CPC ice analysis	**Generated with CFS forcings**	CICE5	NEMS
UFS_p5	CFSR	CPC 3DVar	CPC ice analysis	Generated with CFS forcings	**CICE6**	**CMEPS**

- **Physics settings are kept the same as much as possible except for bug fixes.**
- **Physics tuning is reserved for after engineering is completed**
- **The aim of prototype evaluations to date is to establish baseline skill and ensure technical consistently between prototypes**

Anomaly Correlation Skill for Select Variables/Domains

Weeks 1, 2, 3&4

Notes on the methodology used here

Results are shown for both raw and systematic-error-corrected (sec) anomalies.

The systematic error correction is applied by fitting and removing a smoothly interpolated climatology to both the forecast and observation data. This climatology is produced by fitting the 7 year time series (168 elements, 1st and 15th of each month) to a sine wave of period 365.24 days, plus three harmonics.

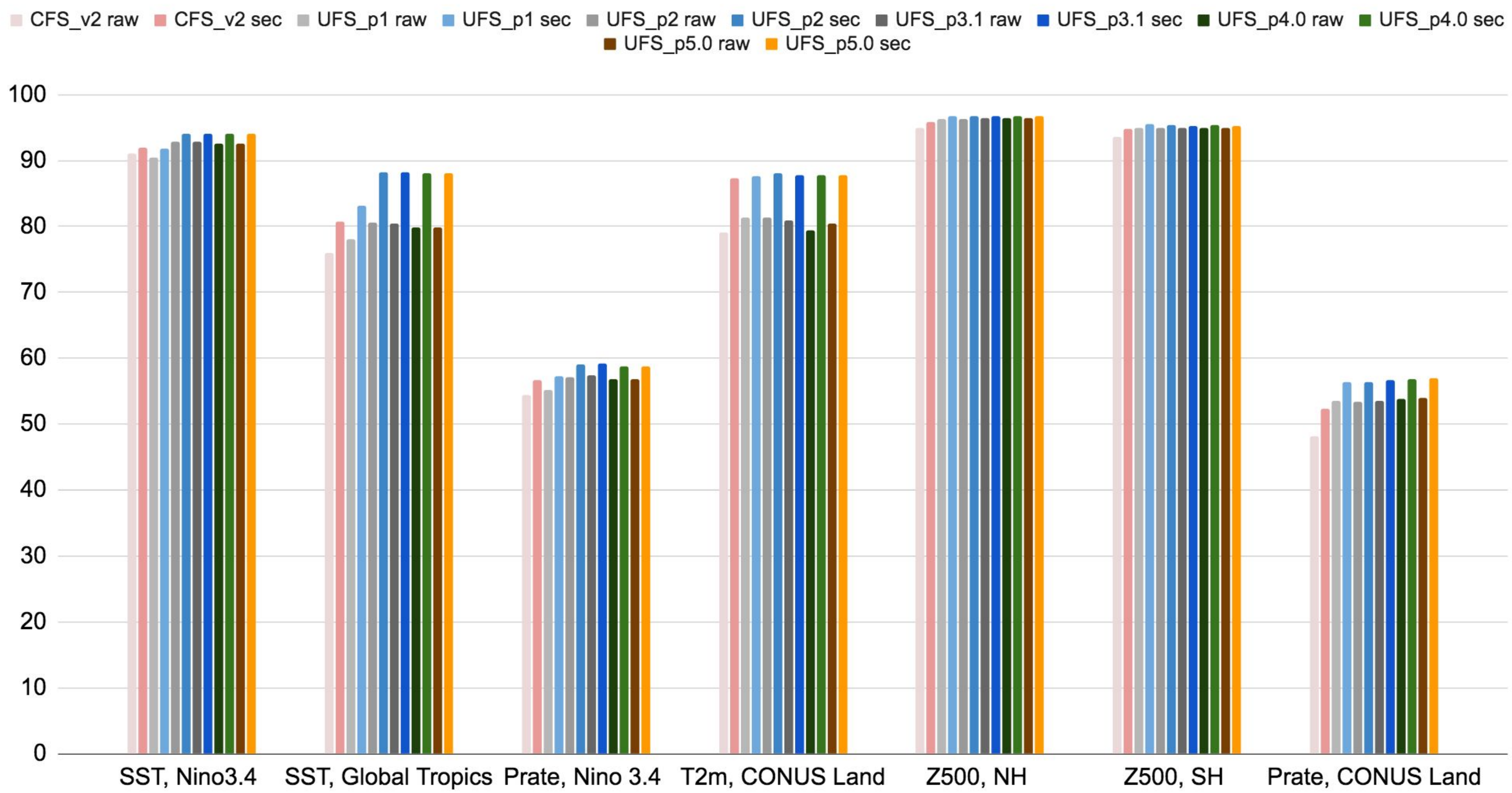
This is done for each gridpoint and variable separately for both for forecasts (as a function of lead) and verifying data.

All forecasts were bias corrected in exactly the same manner.

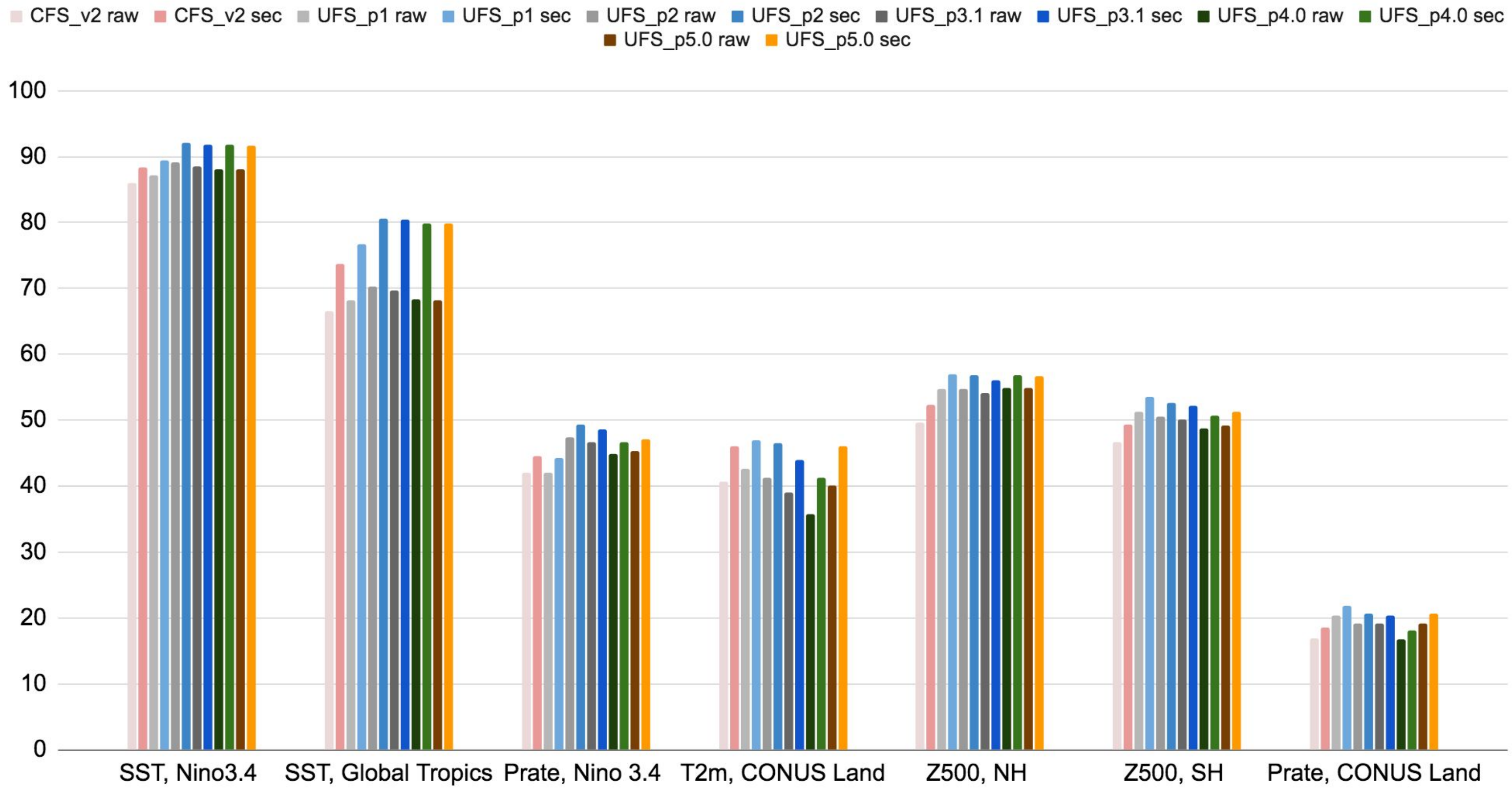
Summary of findings

- Skill improvement from SEC depends on field, domain, lead
- Prototype 5 AC skill is on par with preceding prototypes and above that of the operational CFSv2, with the exception of weeks 3&4 CONUS T2m. The latter is tentatively attributed to absence of lake ice in Prototype 5 which will be corrected in Prototype 6.
- Annual SEC-corrected AC skill scores for P5:
    - Week 1
        - 0.9+ for Z500, Nino3.4 SST
        - 0.85+ for Tropical SST and CONUS T2m
        - 0.55+ for Nino3.4 Precipitation and CONUS Precipitation
    - Week 2
        - ~0.9 for Nino3.4 SST, ~0.8 for Tropical SST
        - ~0.5-0.6 for Z500, 0.4-0.5 for Nino3.4 Precipitation, CONUS T2m
        - ~0.2 for CONUS Precipitation
    - Weeks 3&4
        - ~0.9 for Nino3.4 SST, 0.7-0.75 for Tropical SST
        - ~0.5 for Nino3.4 Precipitation
        - ~0.1-0.2 for Z500 and CONUS T2m
        - <0.1 for CONUS Precipitation

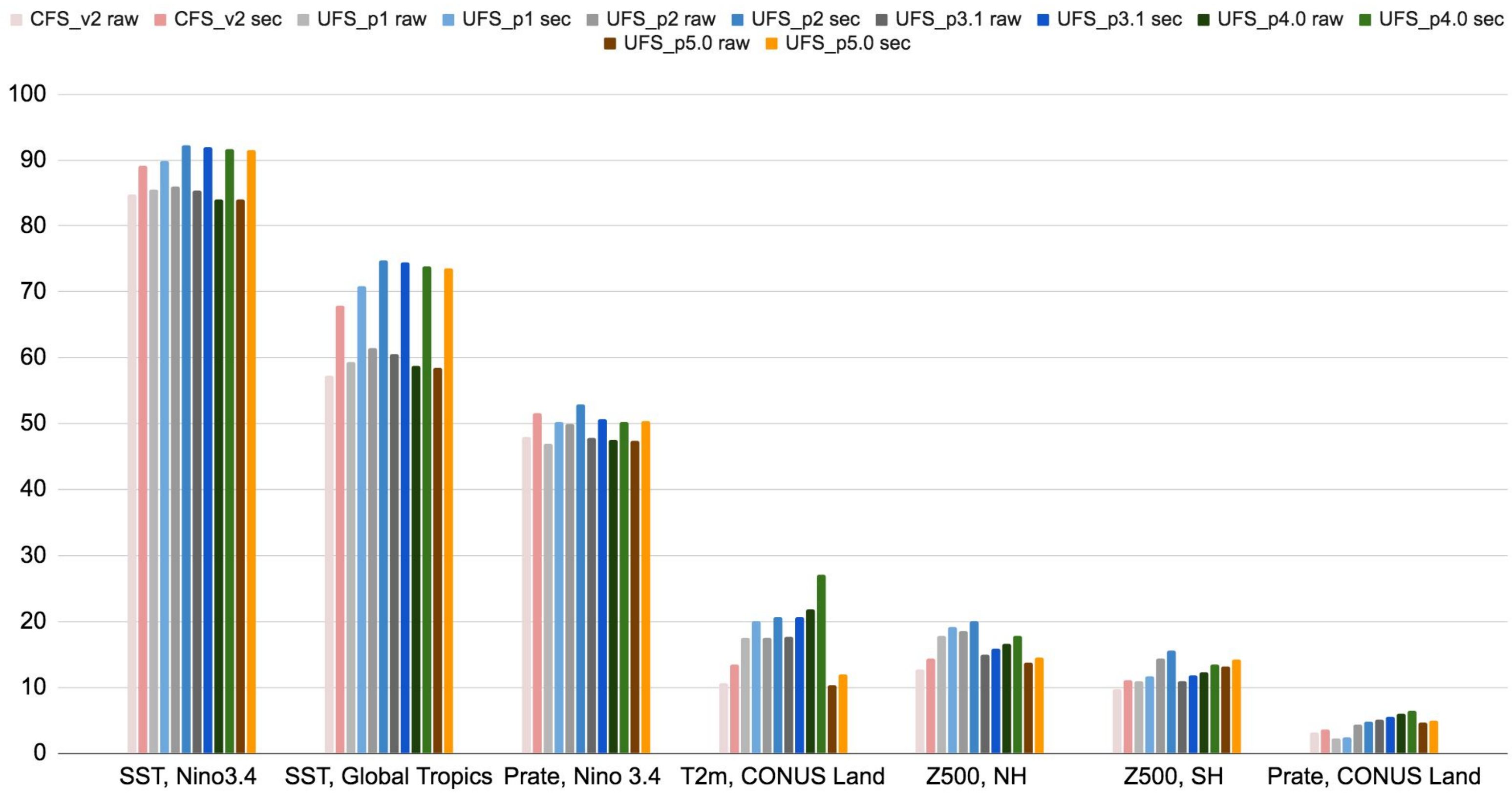
Anomaly Correlations, Week 1



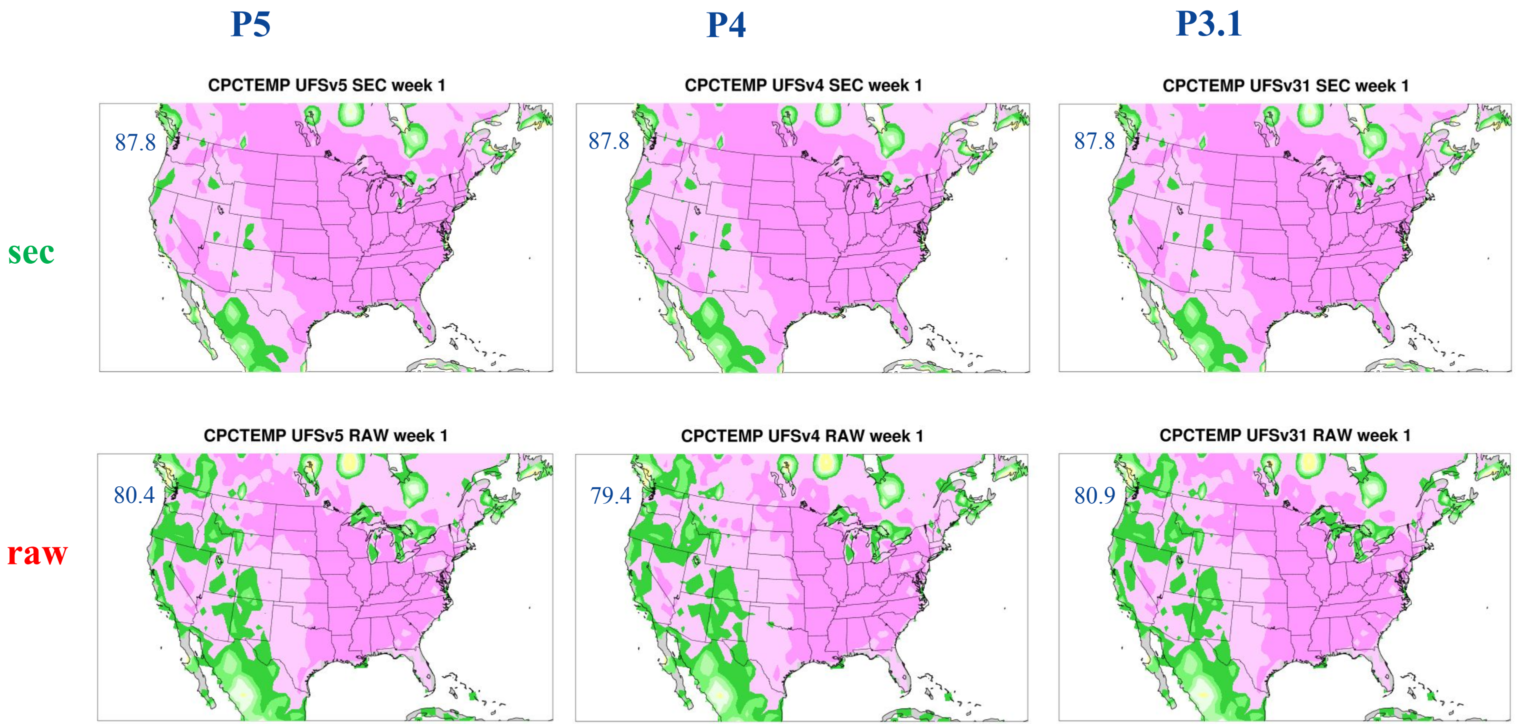
Anomaly Correlations, Week 2

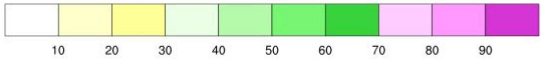


Anomaly Correlations, Weeks 3&4



Anomaly Correlations, T2m, Week 1





*CPC Global 0.5 degree Daily 2-m TMIN/TMAX from:
ftp://ftp.cpc.ncep.noaa.gov/precip/wd52ws/global_temp/
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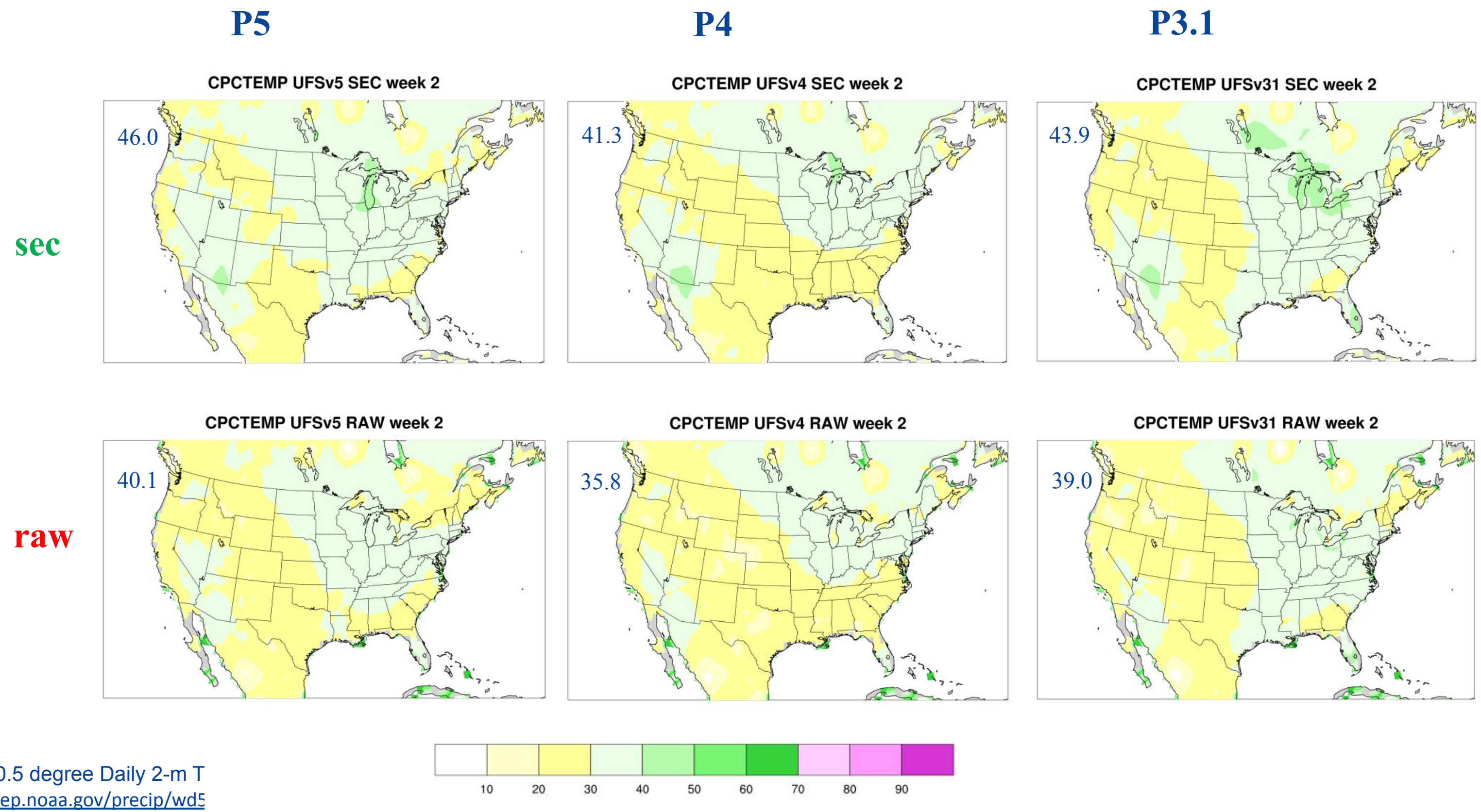
Anomaly Correlations, T2m, Week 2



*CPC Global 0.5 degree Daily 2-m T
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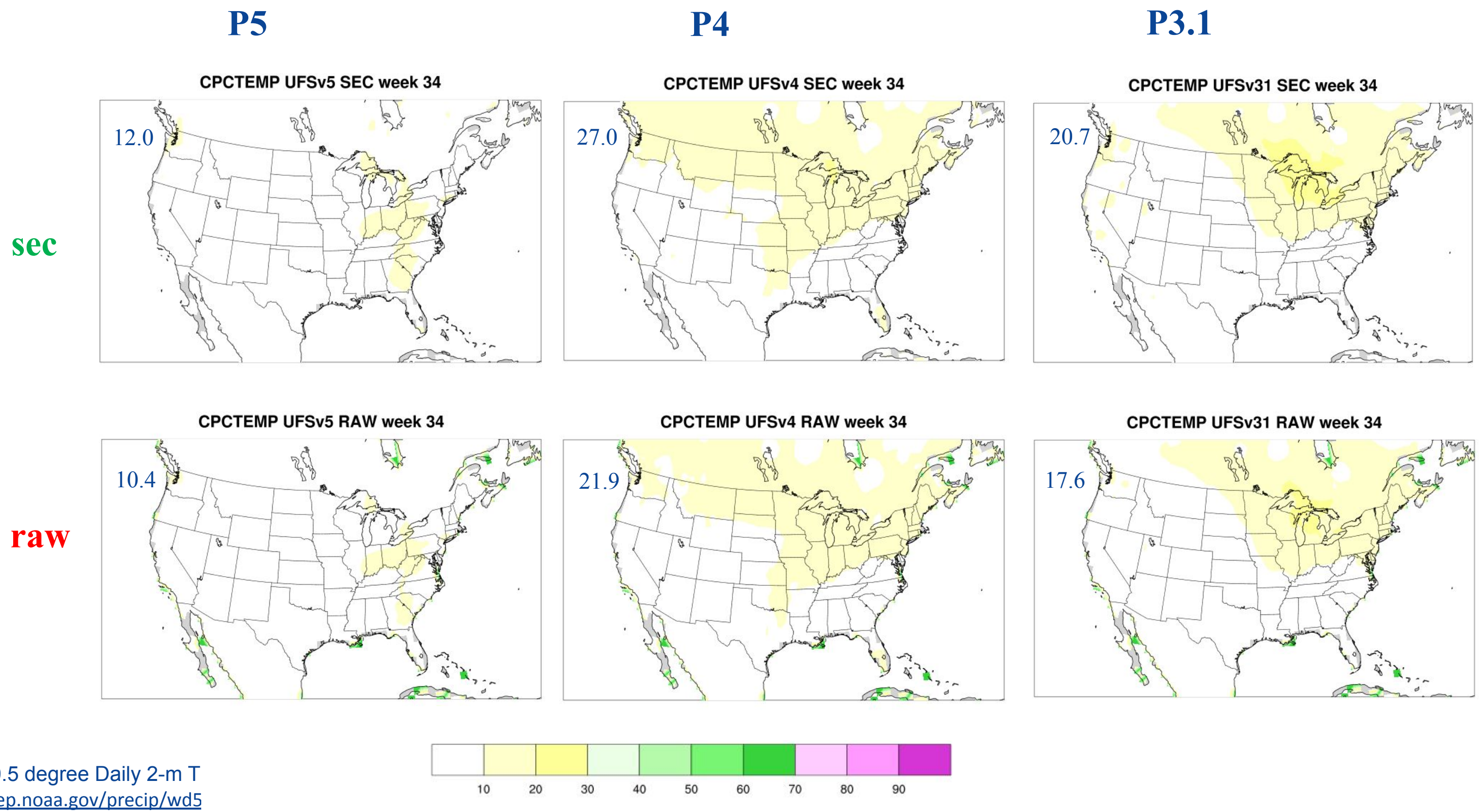
Anomaly Correlations, T2m, Weeks 3&4



*CPC Global 0.5 degree Daily 2-m T
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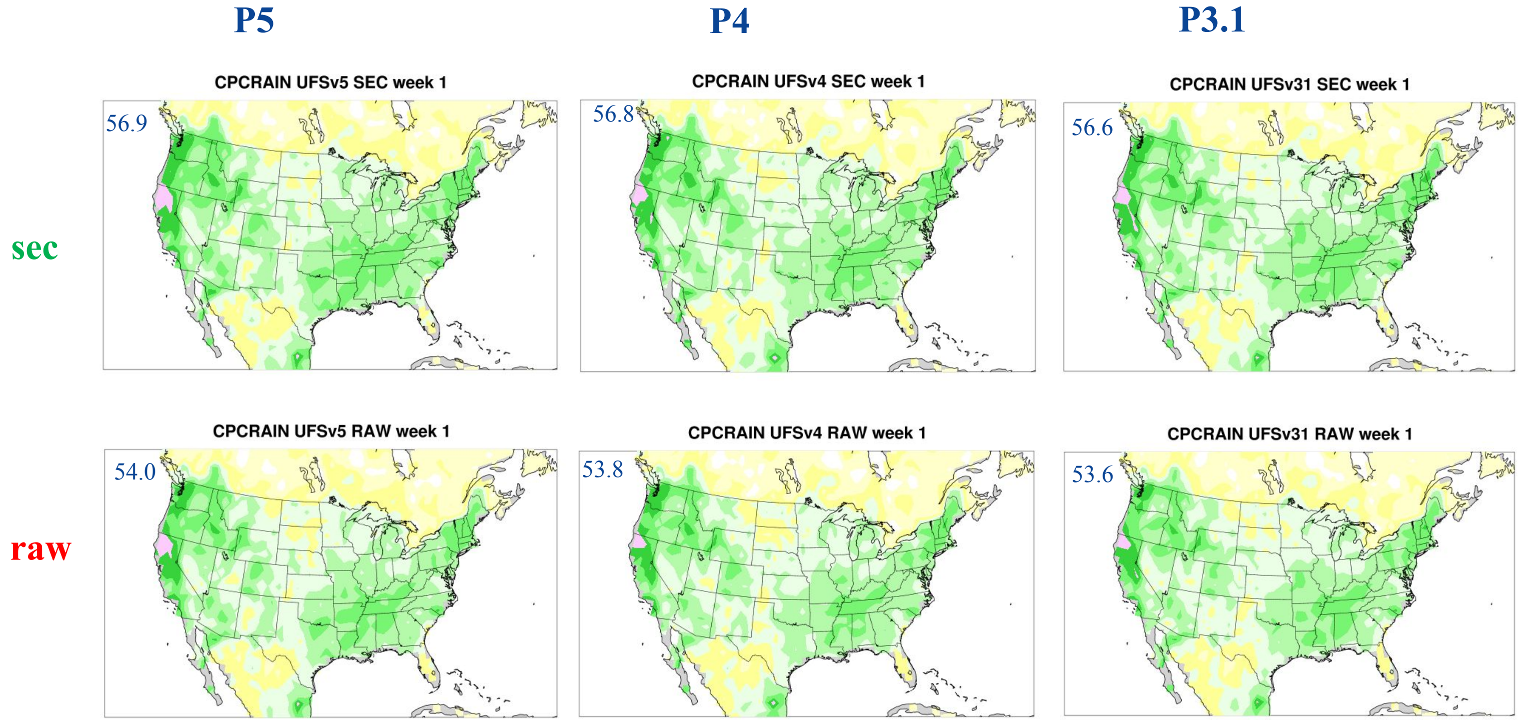
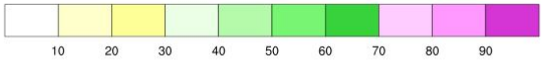
Anomaly Correlations, Precipitation, Week 1





*CPC Global 0.5 degree Unified Rain Gauge data from:
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/
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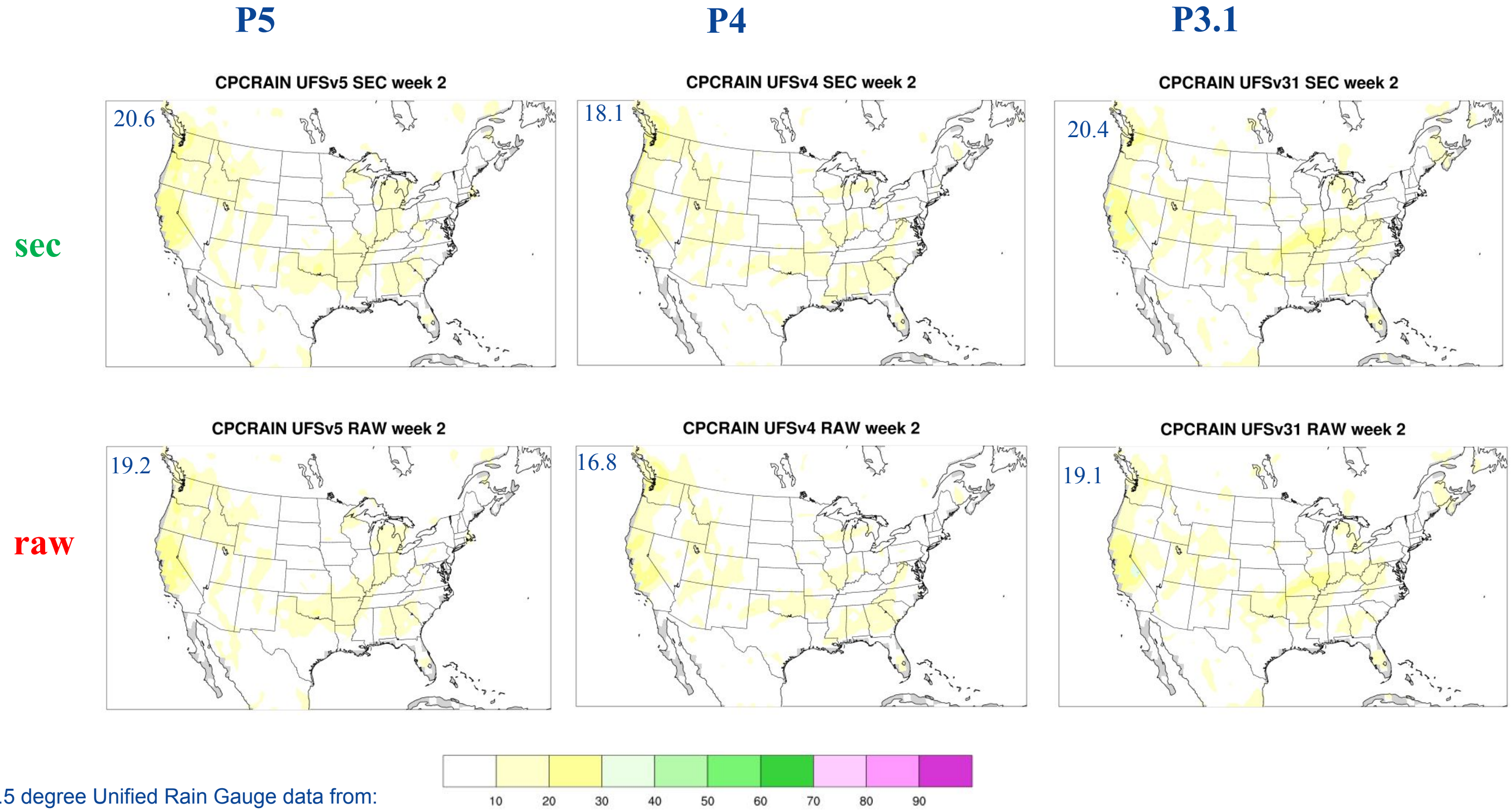
Anomaly Correlations, Precipitation, Week 2



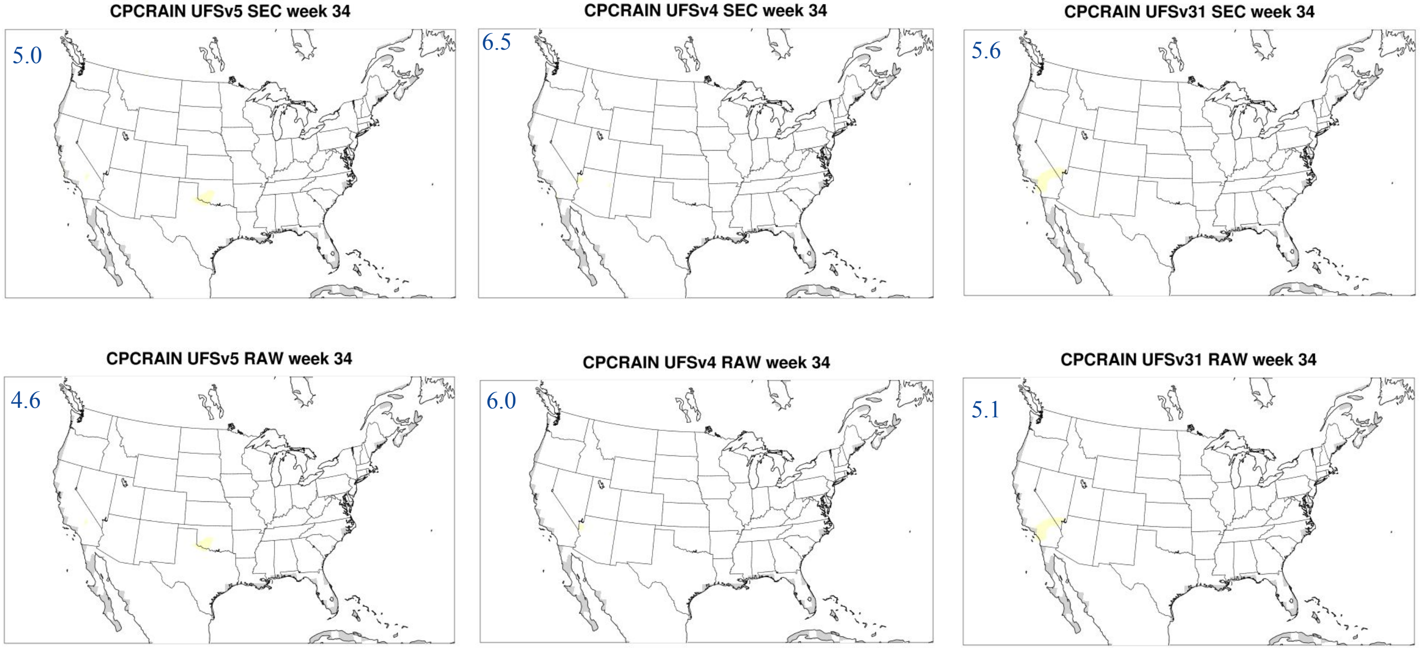
*CPC Global 0.5 degree Unified Rain Gauge data from:
ftp://ftp.cpc.ncep.noaa.gov/precip/CPC_UNI_PRCP/GAUGE_GLB/
e.g., PRCP_CU_GAUGE_V1.0GLB_0.50deg.lnx.YYYYMMDDRT

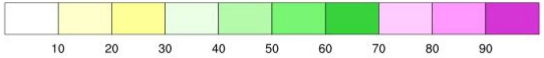
Anomaly Correlations, Precipitation, Weeks 3&4

P5 | P4 | P3.1

sec

raw





*CPC Global 0.5 degree Unified Rain Gauge data from:
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e.g., PRCP_CU_GAUGE_V1.0GLB_0.50deg.lnx.YYYYMMDDRT

MJO

Notes on the methodology used here

The methods to calculate the MJO index RMM1 & RMM2, and bivariate correlation skill are based on Wheeler and Hendon, 2004; Lin et al., 2008

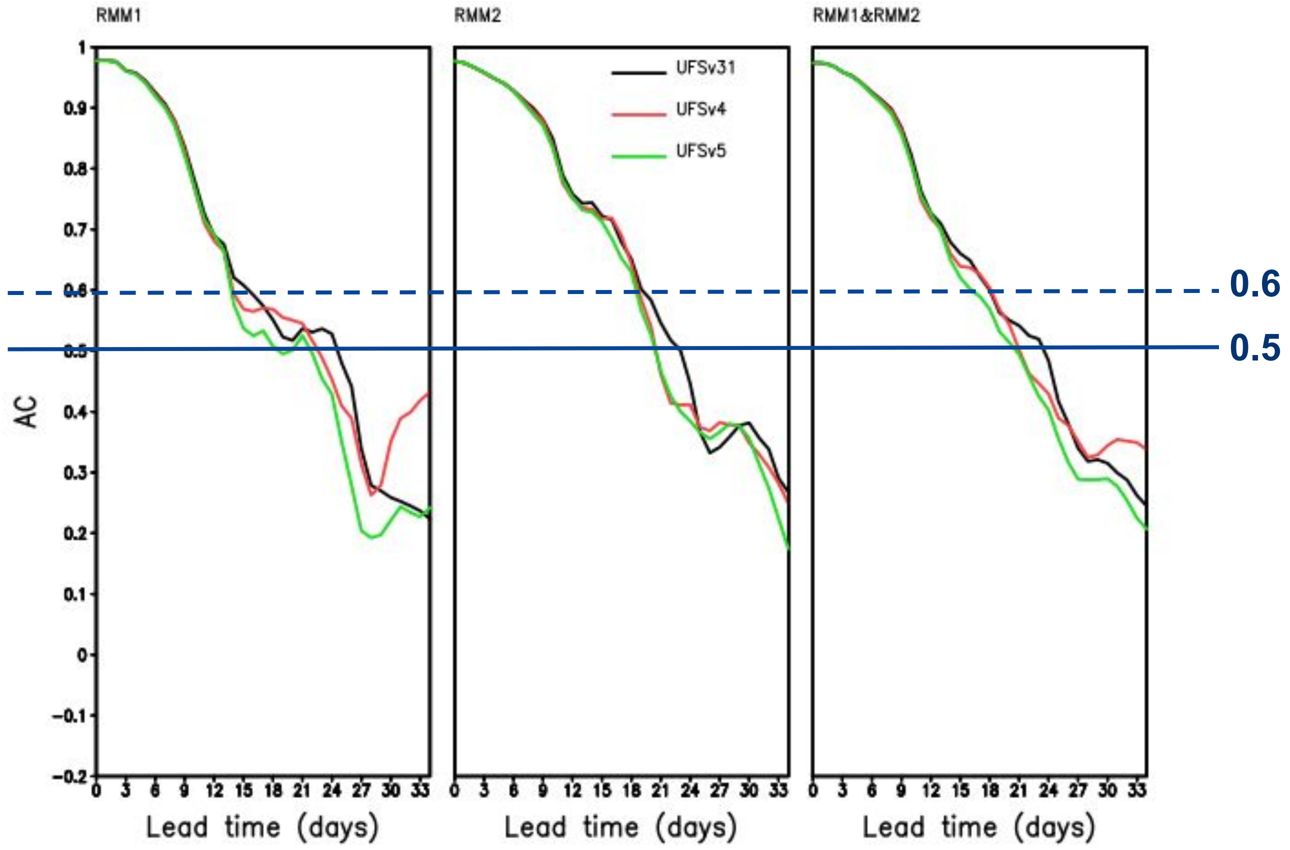
The observations are the daily OLR from the CPC archives and U200 & U850 from CDAS2 in 01jan2010-30Sep2018

All-seasons MJO's two leading modes (RMM1 and RMM2) of the combined timeseries of OLR, U850 and U200 equatorial anomalies are shown. RMM1 series has the largest amplitude in the Maritime Continent and (negative) in the western hemisphere and Africa. RMM2 has largest amplitude in the Western Pacific and (negative) in the Indian Ocean.

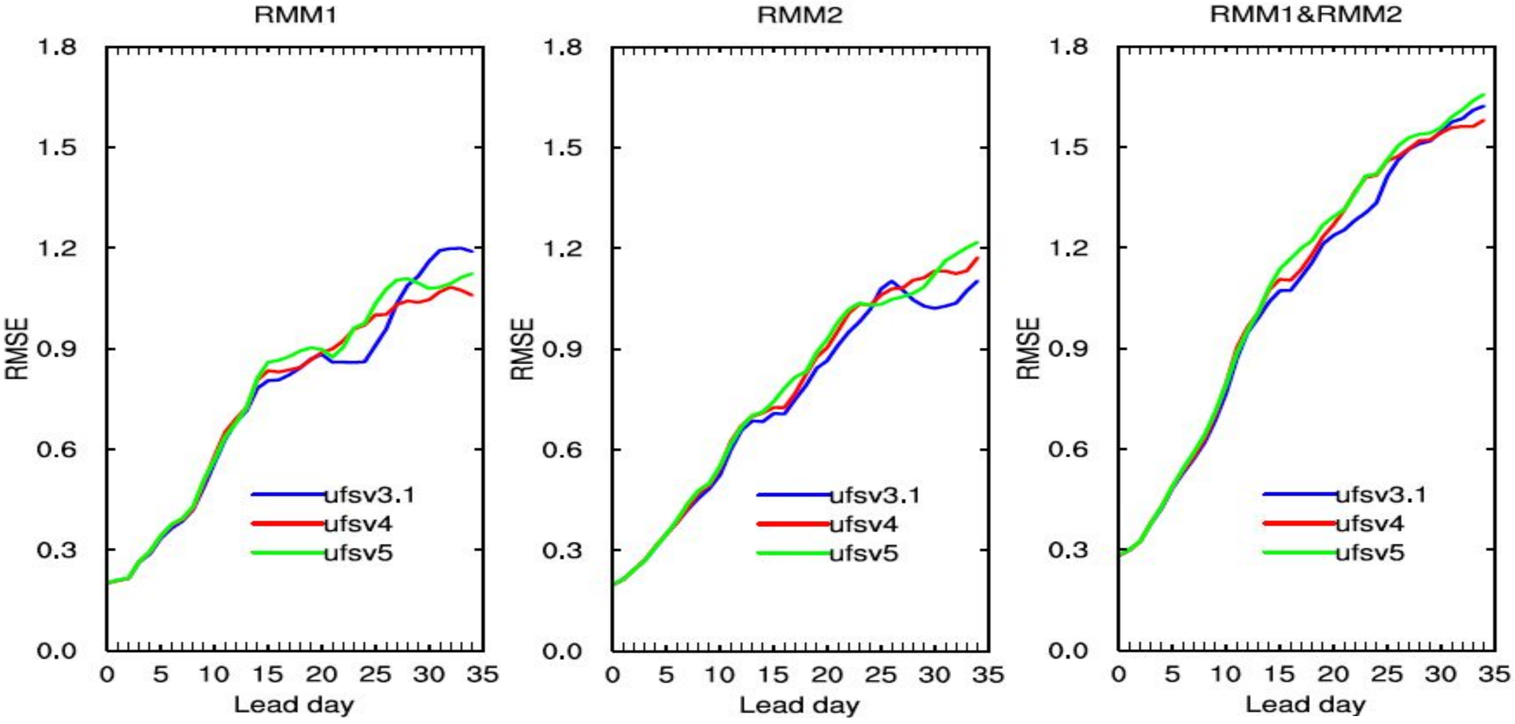
Summary of findings

- **AC skill:**
  - To 0.6: ~16-18 days for combined RMM1+RMM2. Longer by ~3 days for RMM2 than for RMM1
  - To 0.5: ~21-24 days for combined RMM1+RMM2. Similar between RMM1 and RMM2
- **Amplitude error:** MJO is stronger than observations
- **Phase error:** MJO propagation is slower than observations

Anomaly Correlations, MJO: RMM1, RMM2, combined



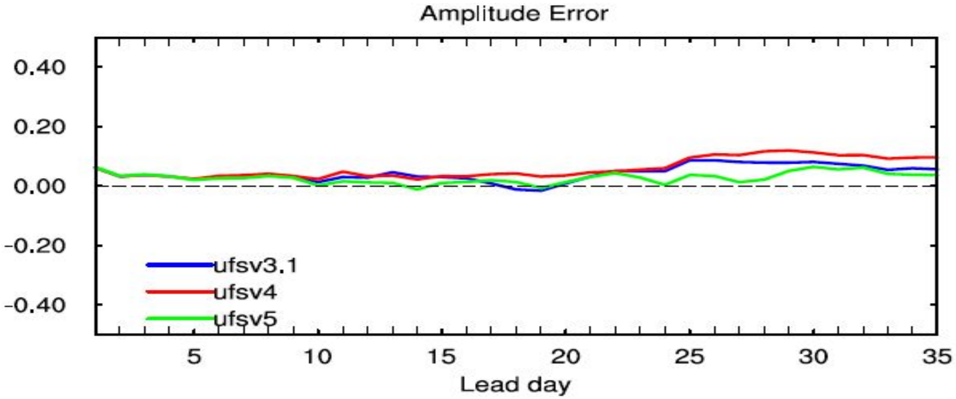
MJO RMSE Skill



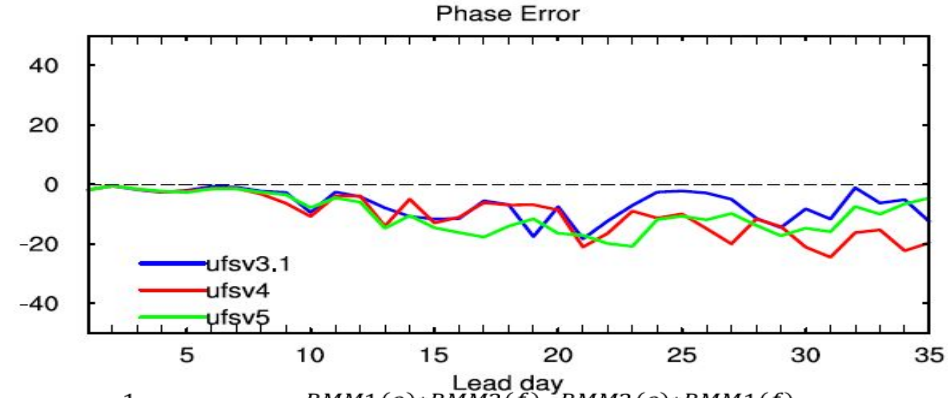
- $RMSE(RMM1\&2) = \sqrt{\frac{1}{N}\sum_{1}^{N}[(RMM1(f) - RMM1(o))^2 + (RMM2(f) - RMM2(o))^2]}$

N=1,168

MJO Amplitude and Phase Error



- AMP=$\sqrt{RMM1^2 + RMM2^2}$
- E(AMP)=$\frac{1}{N}\sum_1^N[AMP(f) - AMP(o)]$, N=1,168
- >0 means stronger; <0 means weaker than obs.



- MJO propagates too slowly

- E(Phase)=$\frac{1}{N}\sum_1^N tan^{-1}(\frac{RMM1(o)*RMM2(f)-RMM2(o)*RMM1(f)}{RMM1(o)*RMM2(o)+RMM1(f)*RMM2(f)})$ $Kim\ et\ al\ (2018)$
- >0 means faster; <0 means slower than obs.

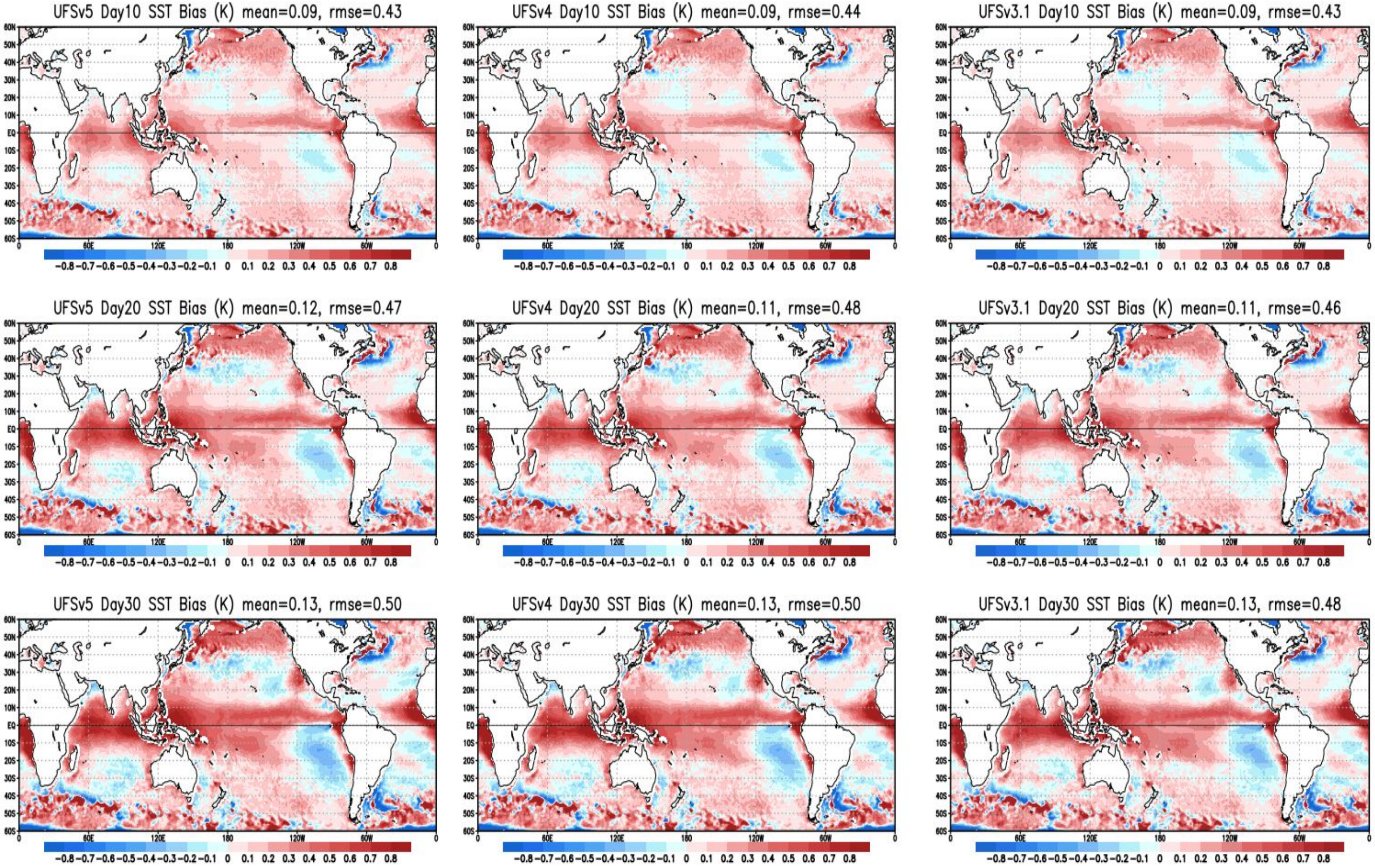
Annual mean biases

Days 1-10, 11-20, 21-30

Summary of findings

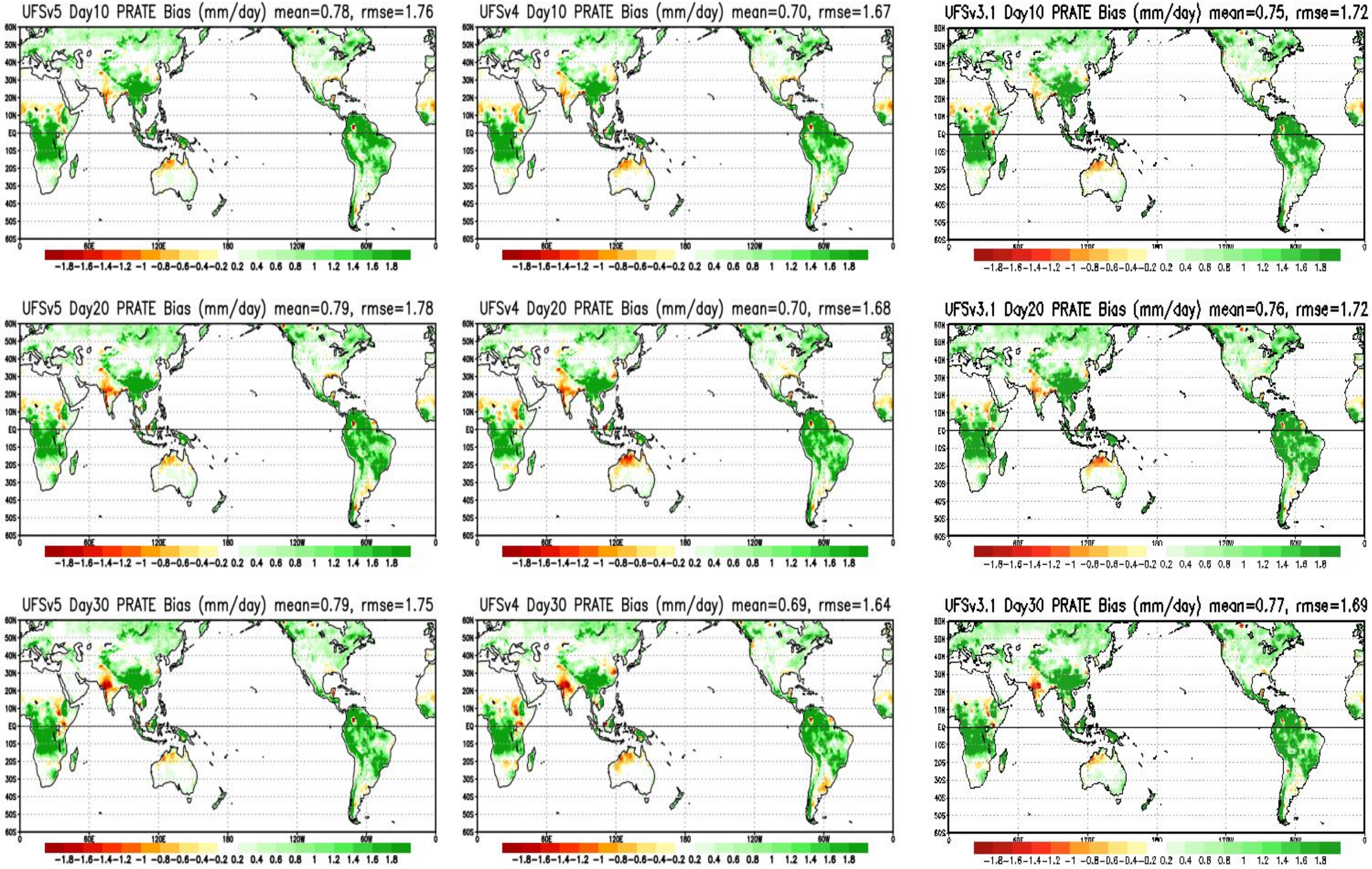
- **SST**: Generally warm bias, particularly pronounced along ITCZ, Maritime continent, and western continental coasts. Cold bias in cold tongue region and near Gulfstream and Pacific ocean ~30N. Both warm and cold bias increase with lead time
- **Land Precipitation**: Generally wet bias, particularly strong in equatorial Africa and South America and southeast Asia. Dry bias in Indian subcontinent, northwestern Australia, and northern sub Saharan Africa
- **Land T2m**: Generally warm bias, with the exception of Central and South America and southeast Asia. For CONUS the warm bias affects the western US. Warm bias increases with lead time.
- **Z500:** Area-averaged bias is small and positive, somewhat increasing with lead time

SST bias



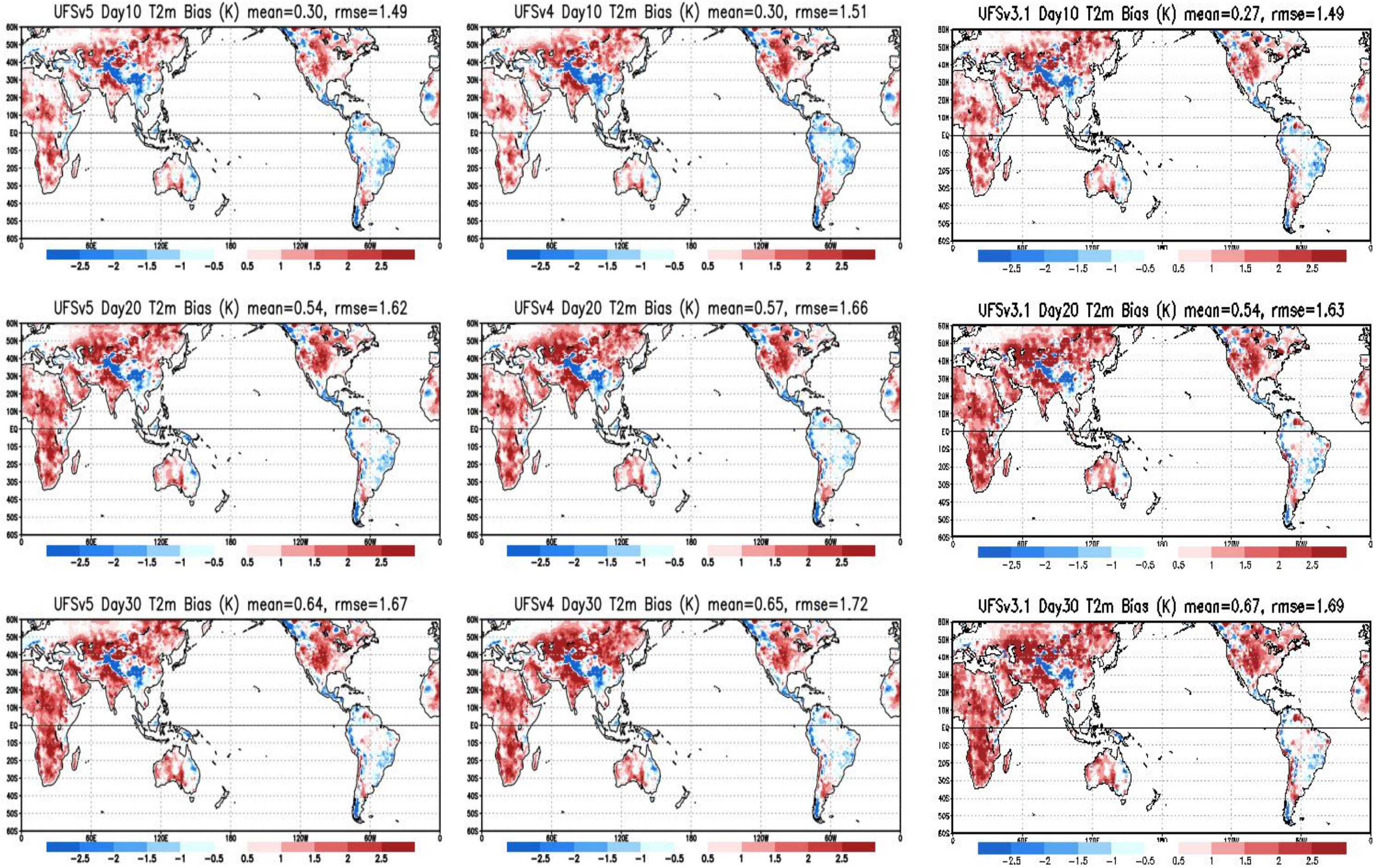
OSTIA SST used for verification

Precipitation bias (land)



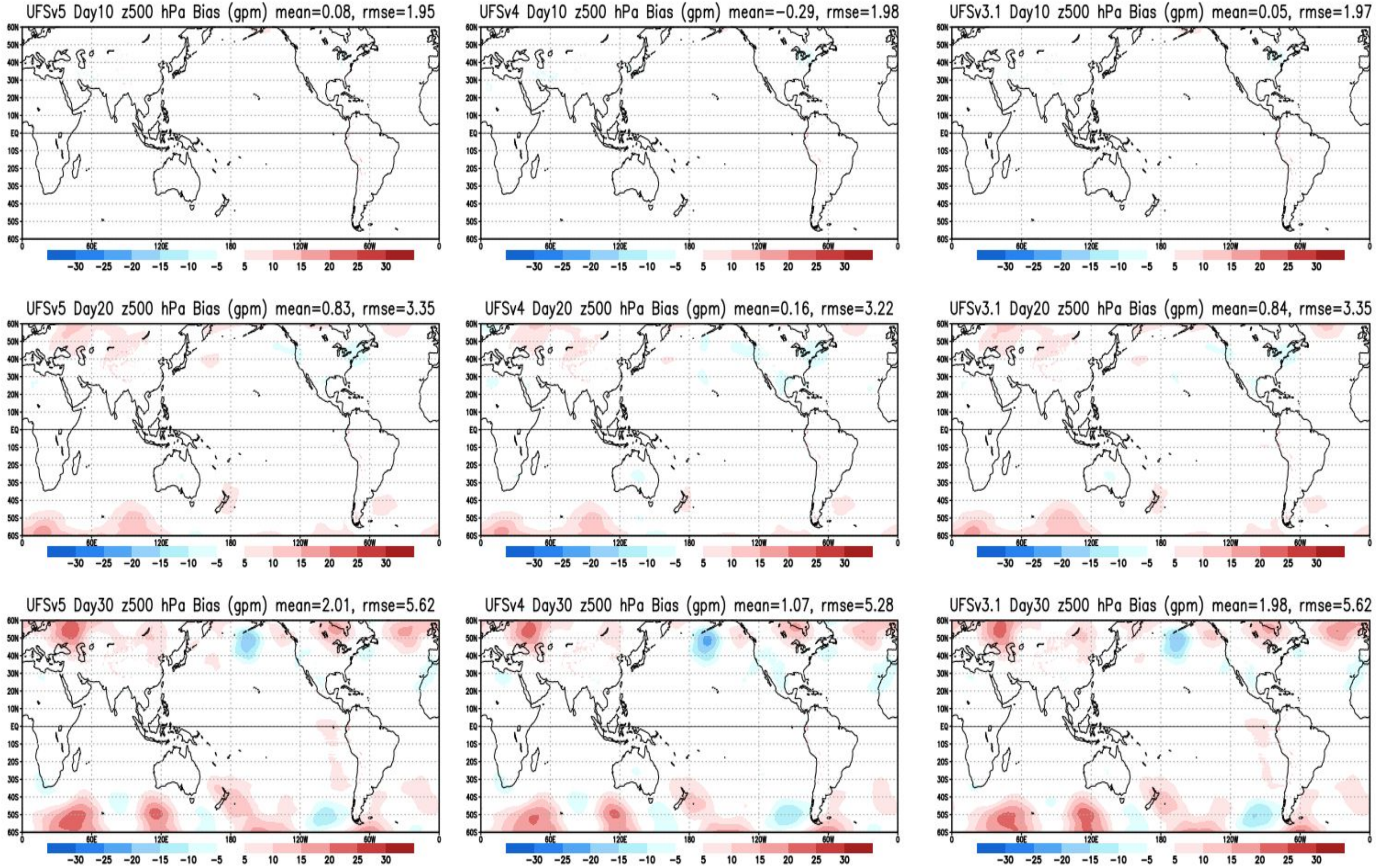
CFSR used for verification

T2m bias (land)



CFSR used for verification

Z500 bias



CFSR used for verification

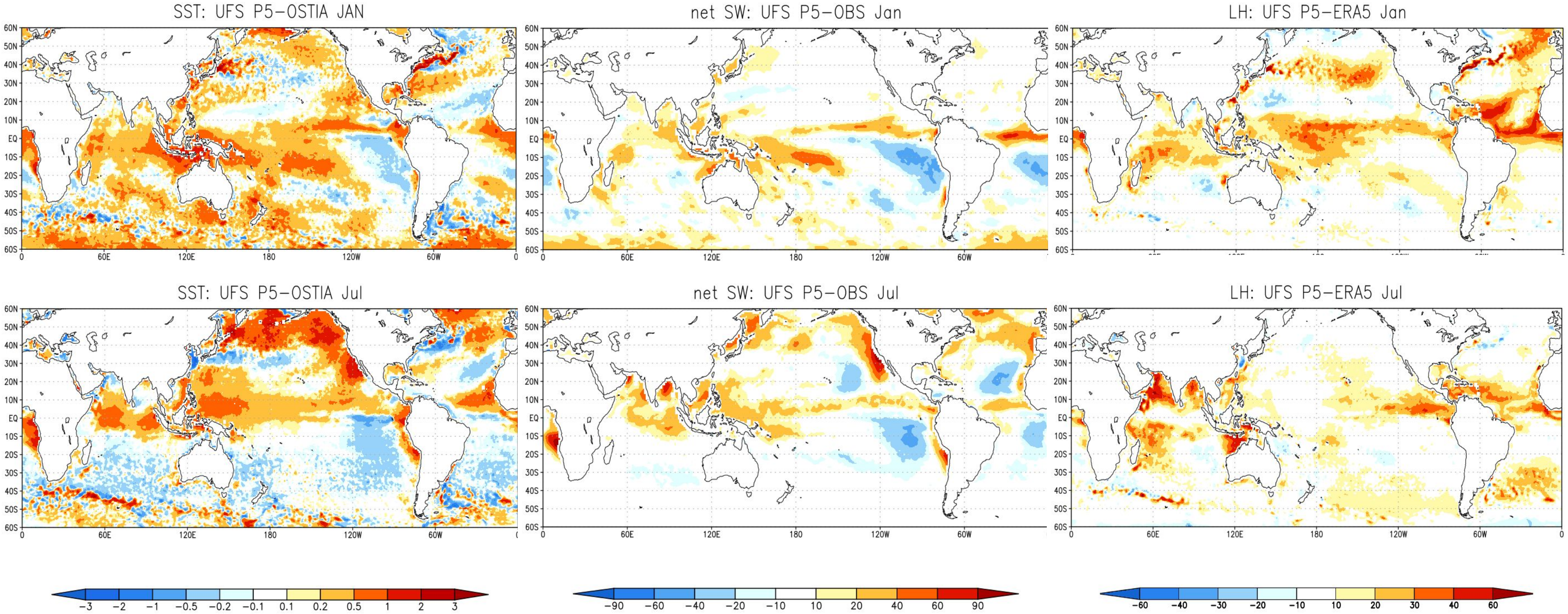
Ocean flux biases

January/July

Summary of findings

- **SST**: Warm bias along ITCZ, Maritime continent, and western continental coasts. Tendency for warm bias at higher latitudes in winter hemisphere. Cold bias in cold tongue region.
- **Net Shortwave Radiation**: Similar pattern and sign to SST bias
- **Latent Heat Flux**: Generally positive bias, more pronounced along ITCZ, and around 40° latitude of the winter hemisphere. Particularly large in the North Atlantic in winter
- **Net Longwave Radiation**: Generally negative bias, especially pronounced in the western coasts of continents and high latitudes where SST has warm bias. No strong bias along ITCZ.
- **Sensible Heat Flux:** Positive bias in high latitudes of winter hemisphere: Kuroshio and Gulfstream in NH winter and in high southern latitudes in SH winter. No strong bias in the tropics
- **Wind Stress:** Positive bias in high latitudes of winter hemisphere and Arabian Sea in summer

P5 Jan/Jul (SST, netSW, LH)



P5 Jan/Jul (netLW, SH, Tau)